

# Supervisory control system for distributed energy resources and microgrids

---

23 Apr 2014

Michael Stadler

Team: C. Marnay, C. Milan, D. Baldassari,  
G. Cardoso, J. Eto, J. Tjaeder,  
M. Stadler, N. DeForest, S. Wang,  
T. Brandt, W. Feng

[mstadler@lbl.gov](mailto:mstadler@lbl.gov)  
[building-microgrid.lbl.gov](http://building-microgrid.lbl.gov)





# Big Picture

# Overview

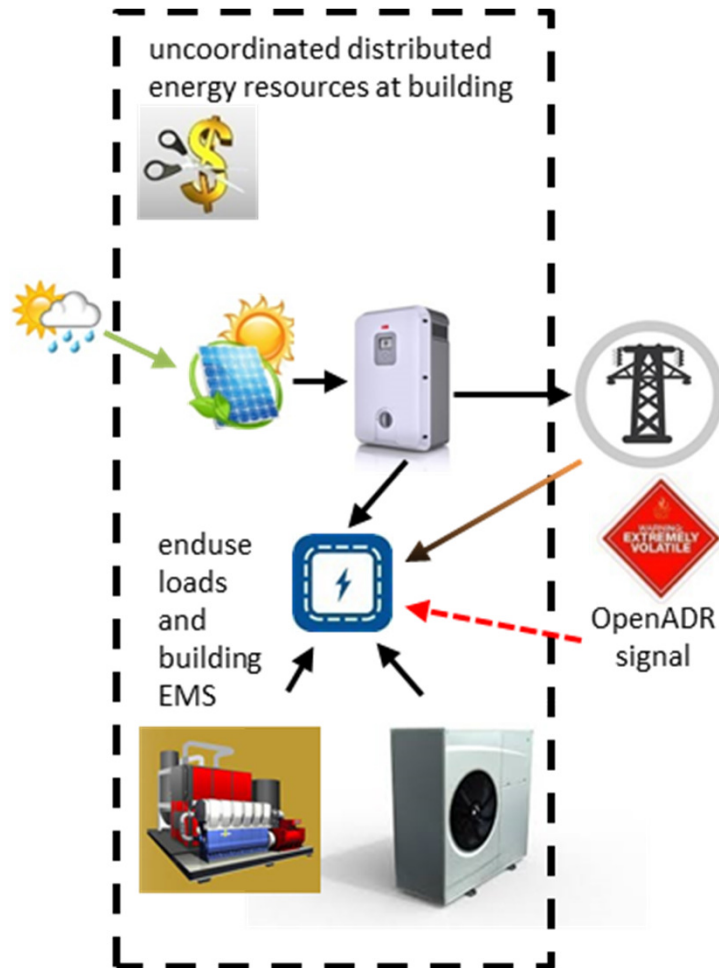
---



## Challenge:

- demonstrate the use of **day-ahead optimization** and **real-time control** to implement **optimal system dispatch**
- consider **grid connected** and **islanded** operation modes
- distributed systems with **multiple** on-site energy **resources**: storage, PV, CHP,...
- use **weather data** to forecast PV generation
- use **historic data** to forecast energy loads
- use **Operations DER-CAM** to produce **cost-optimal** day-ahead dispatches and feed them to the **SCADA** system
- emphasis on **optimal battery scheduling** to ensure PV exports within maximum levels

# Current Systems



- disconnected individual assets
- no load forecasting nor generation planning
- no coordinated generation and load management
- no communication



- ⦿ lost revenues
- ⦿ volatile resources
- ⦿ no reactive / active power control
- ⦿ no coordinated sharing of resources
- ⦿ no islanding

# Future Systems

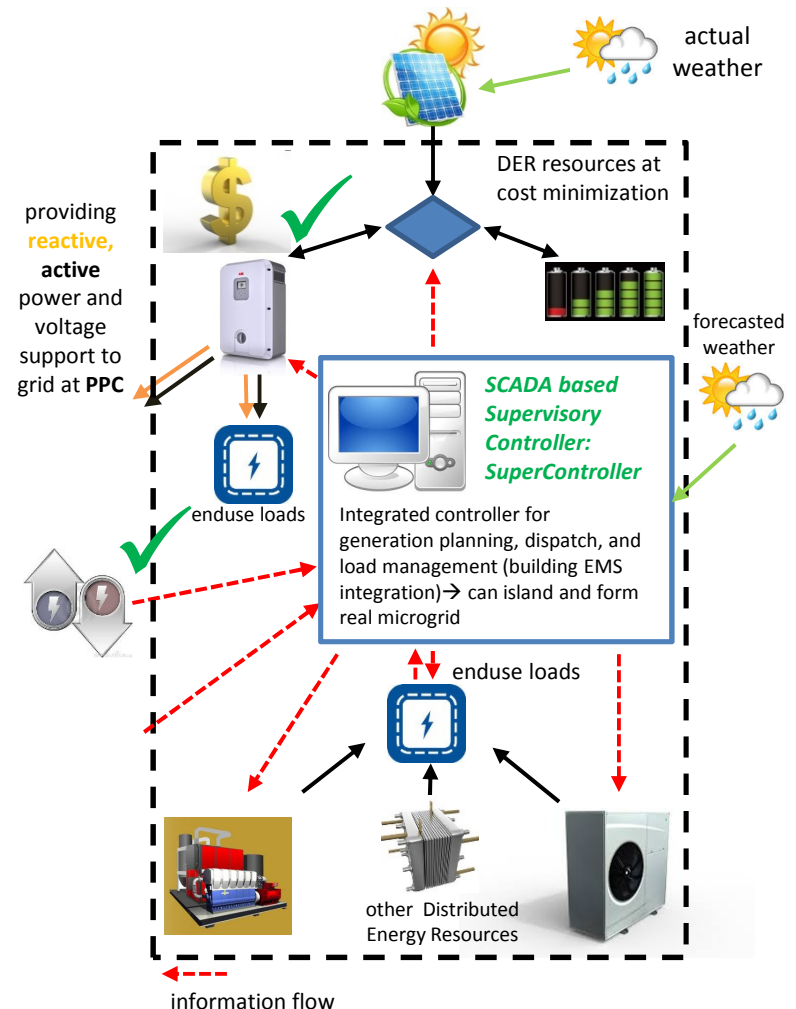


## Integrated assets with LBNL's Supervisory Control system:

- load forecasting and generation planning to minimize costs
- coordinated generation / dispatch and load management
- open to any standard SCADA system and any vendor
- connected DER and DR assets



- ☺ cost minimization
- ☺ reactive / active power control (smart inverter)
- ☺ two possible operation modes
  - grid connected
  - islanded
- ☺ coordinated sharing of resources





---

## Current Work for PV and Storage at Fort Hunter Liggett (FHL) (Small CPUC Grant to Start the Work)

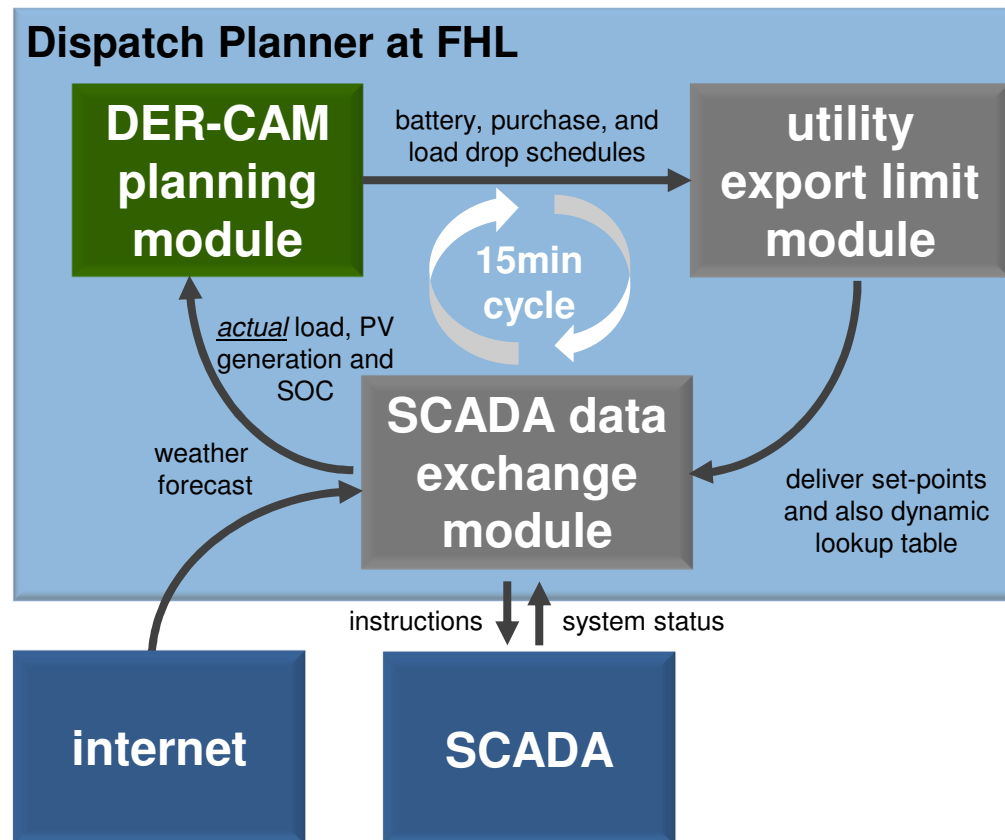
# Overview FHL



- large 2 MW PV and battery system 1 MWh
- in the future 8 MW of PV and full microgrid
- no supervisory controller available



# Current DER-CAM Model at FHL





# Forecasting Load and PV Generation

---



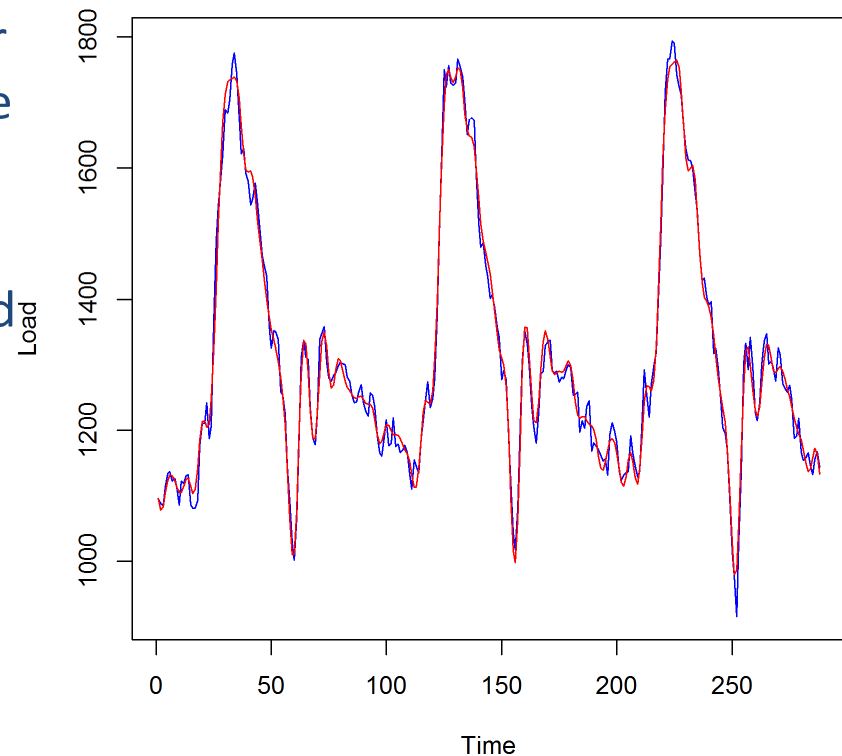
For real-time optimization, load and PV generation need to be forecasted for FHL. Both factors are driven by *different influences*.

- *load is driven by base occupancy* and shows relatively stable daily patterns. Influence of outside temperature appears to be relatively minor.
- *PV is driven by solar radiation*, which depends on the position of the sun and various seasonal patterns. Patterns can be very volatile due to clouds.
- load data is available in 15-minutes intervals as net load, weather data is available in hourly intervals, PV data varies between 15 minutes and hourly

# Forecasting Load



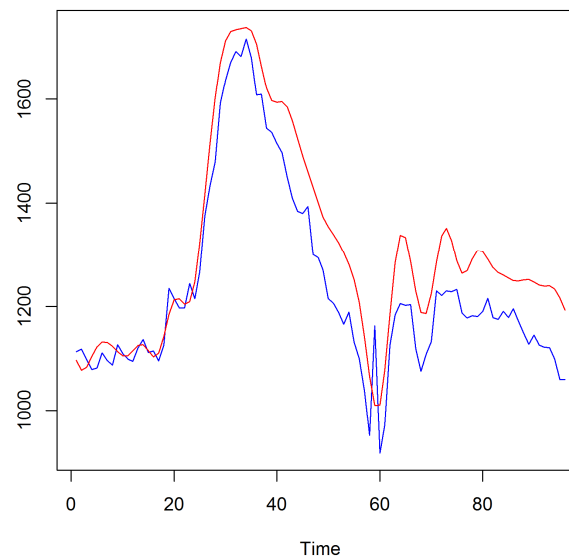
- load shows consistent patterns for each day of the week (holidays are similar to Sundays)
- to forecast next Tuesday, the past three Tuesdays are considered and a Fast Fourier Transformation (FFT) is used to extract the most important frequencies
- the resulting curve contains the main pattern without noise



# Forecasting Load



average error over a day is around 10%



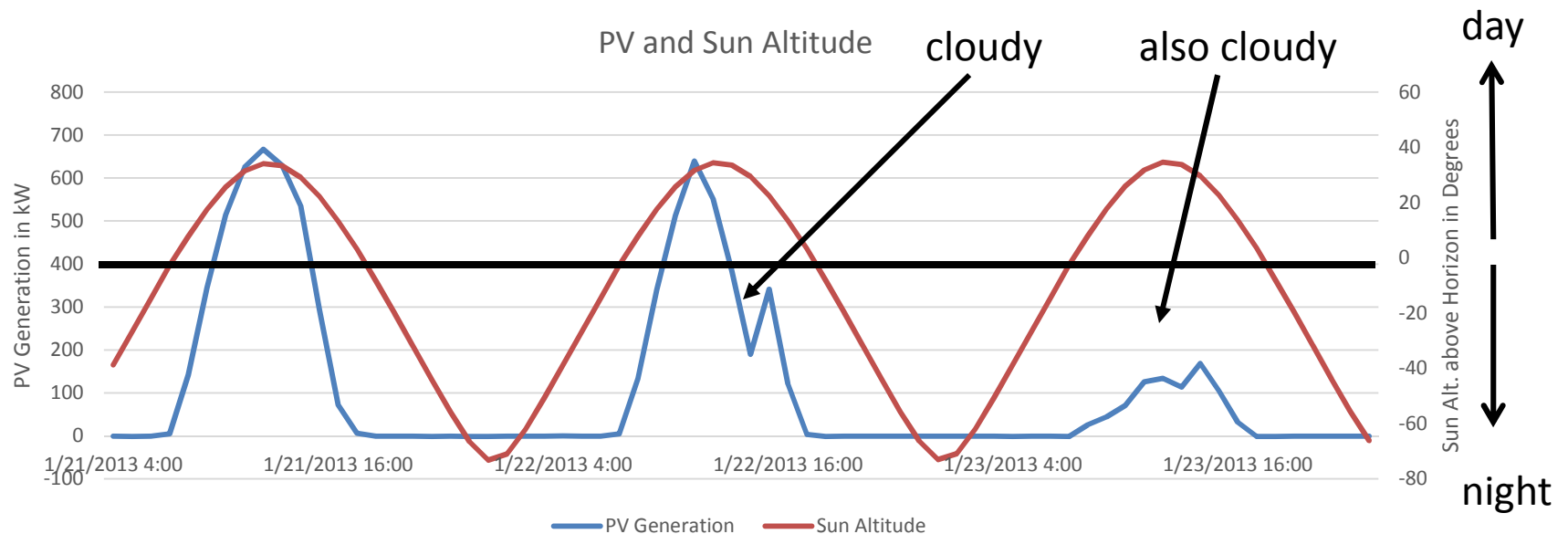
- ☹ change in base occupancy is only slowly incorporated by FFT
- ☺ forecasted values are multiplied with a parameter  $d$  that starts out at 1 and decreases / increases whenever deviations between forecasted and actual values exceed a certain threshold

# Forecasting PV



Weather forecast data is available hourly and difficult to interpolate (qualitative data like “cloudy”).

- solar radiation depends on position of sun and seasonal factors
- in the short term, these seasonal factors are fixed and sun altitude becomes dominant influence of clear-sky PV generation



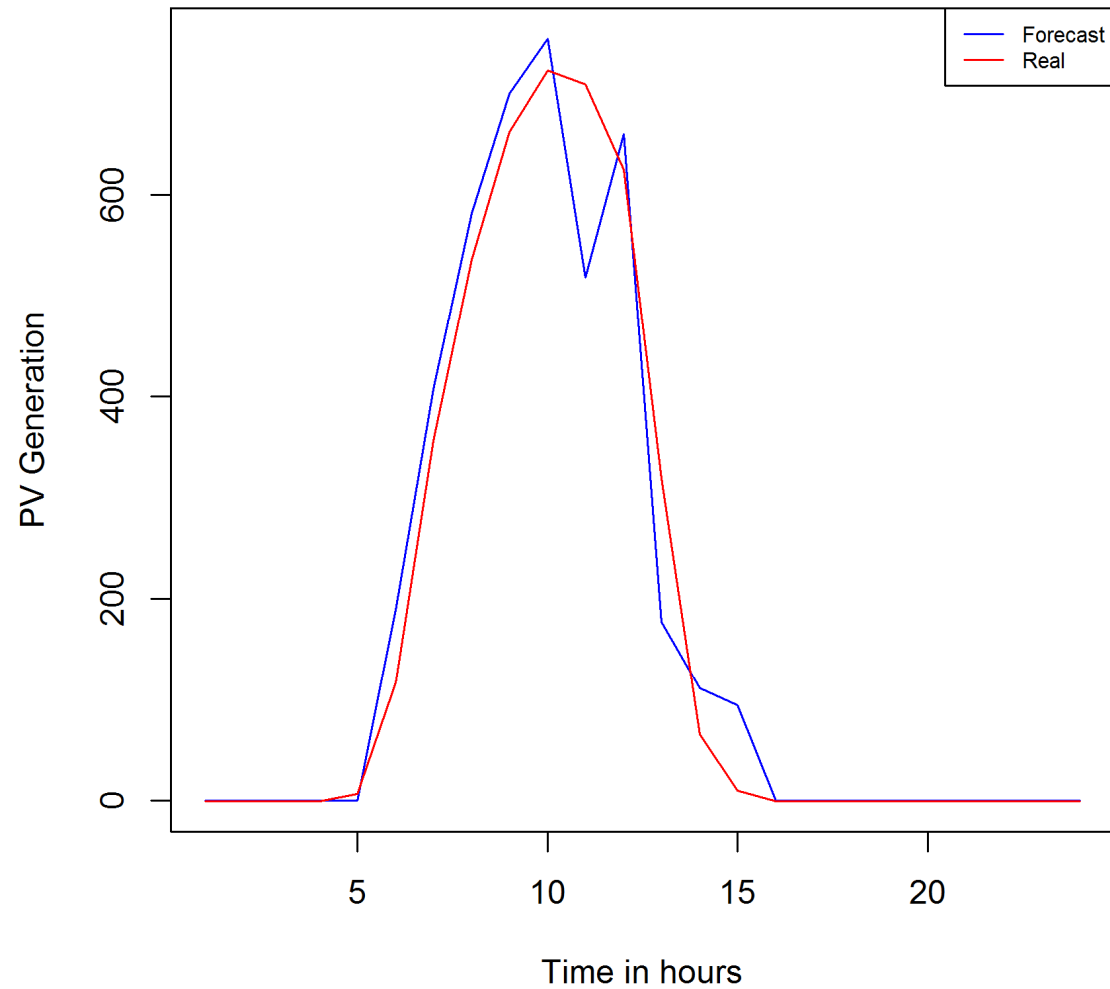
# Forecasting PV

---



- clear-sky PV generation is forecasted using a simple linear model that relates sun altitude to power generated of the past 30 clear-sky hours
- for fog, haze, and clouds clear-sky PV generation is modified by a specific factor to get expected generation
- deviation (i.e. (forecast-real)/real) is less than 5% in 80% of the cases and less than 10% in 90% of the cases
- forecast errors mainly due to inaccuracies in qualitative data (“03 PM overcast” does not necessarily imply that it is overcast for the entire hour)

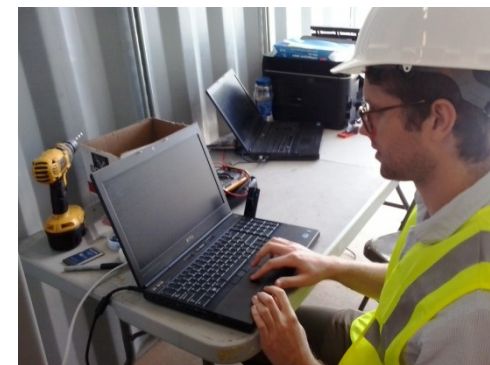
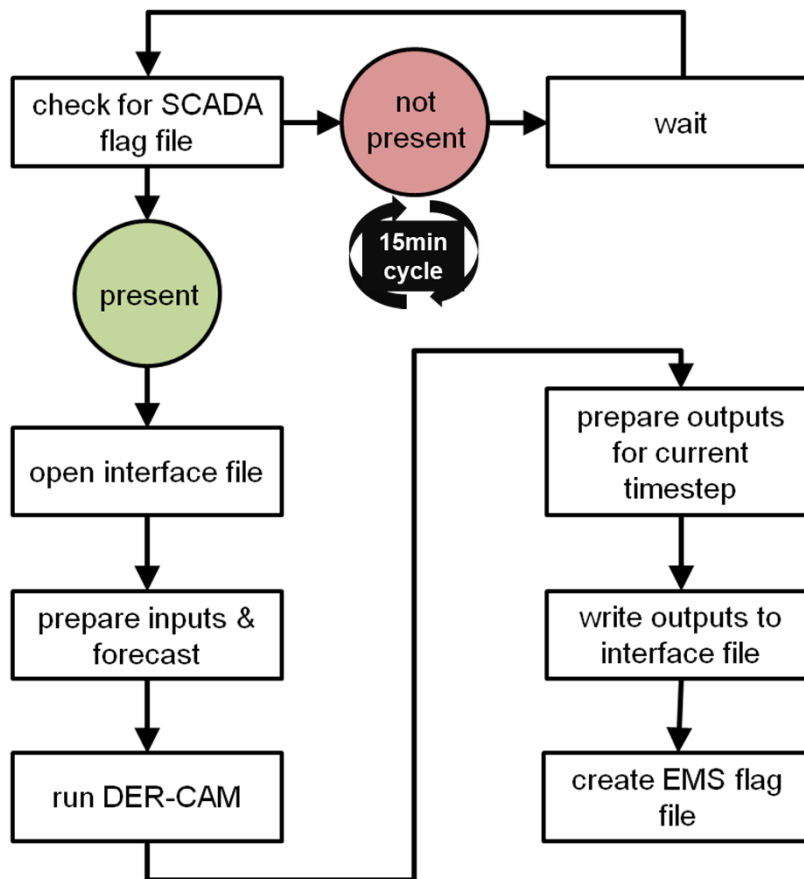
# Forecasting PV



# SCADA interface

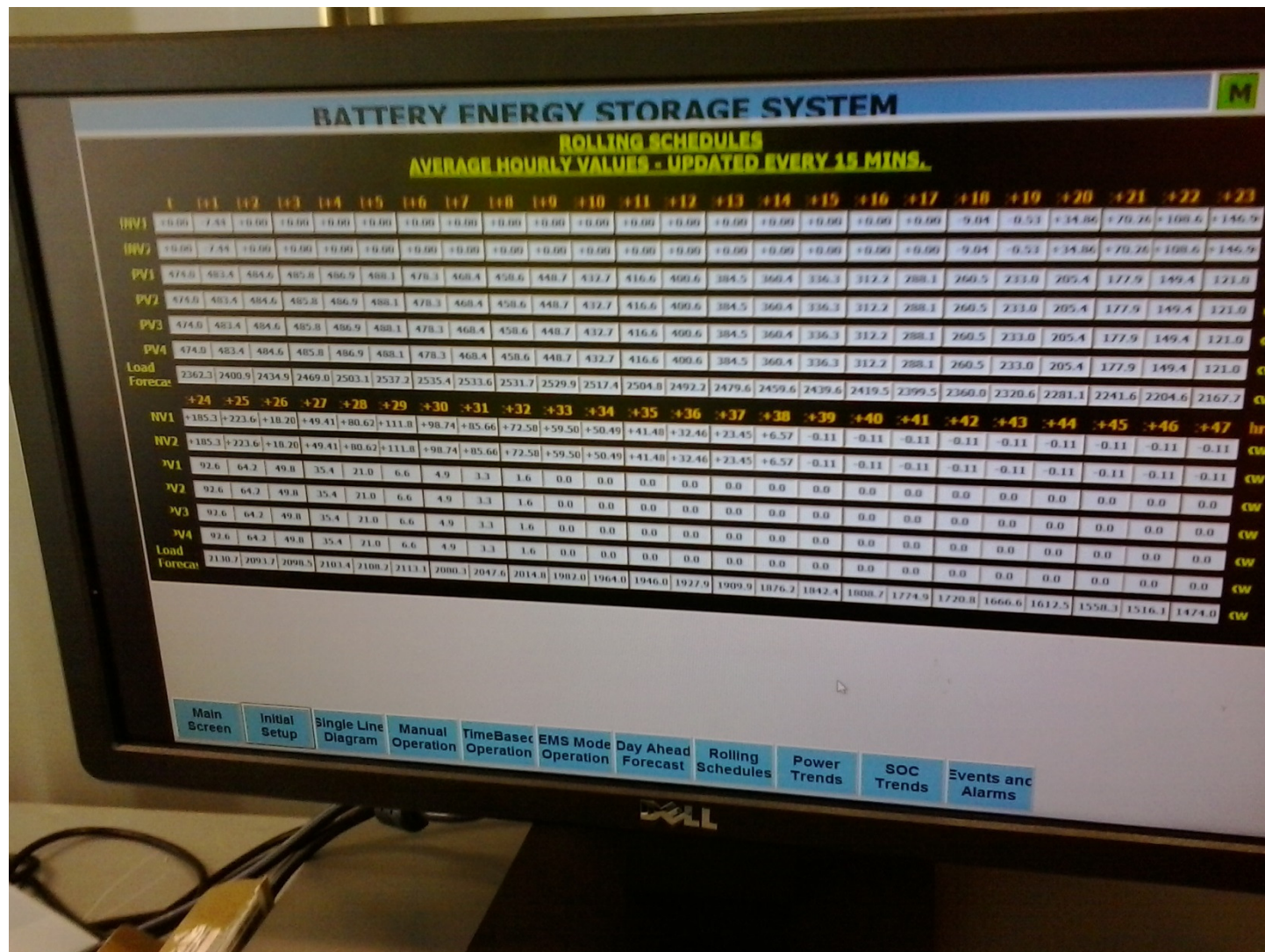


early development stages achieved successful feeding of Operations DER-CAM dispatches in the FHL SCADA system



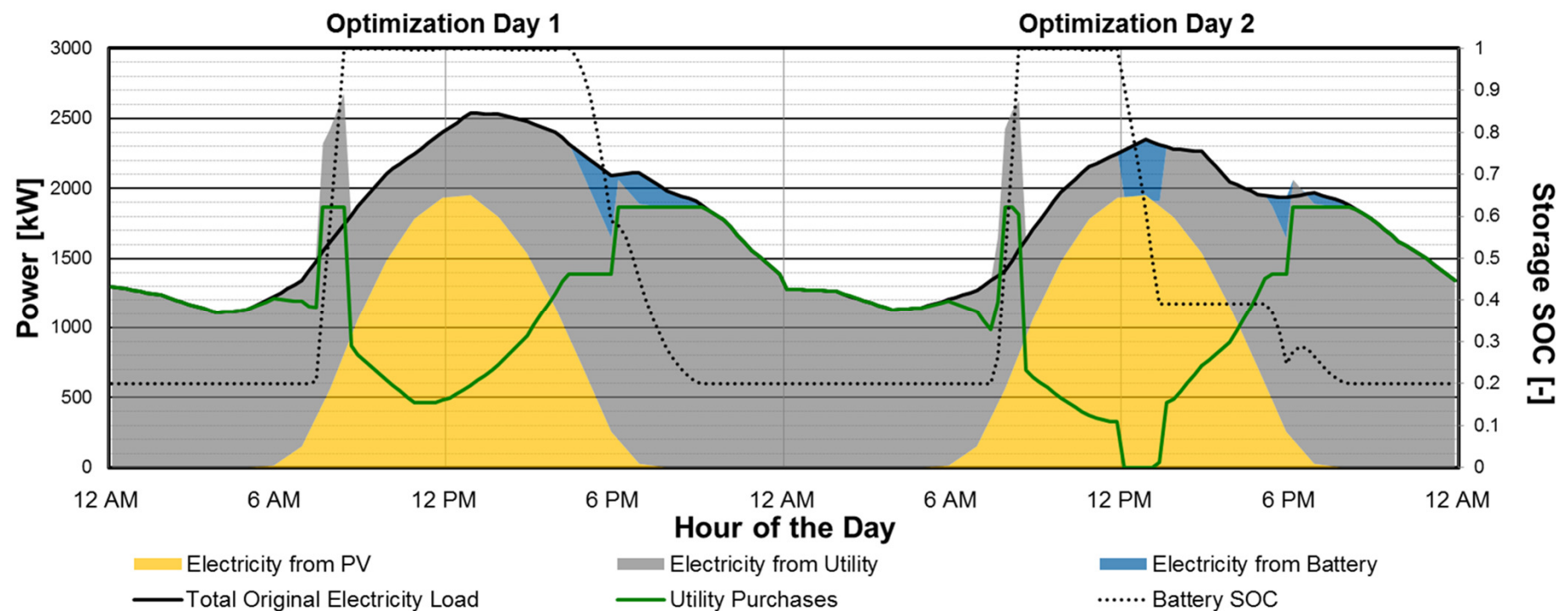


# SCADA Interface





# DER-CAM Output: Example



# End

---



Thank you!

Questions and comments are very welcome.